Queensland University of Technology
Brisbane Australia

This is the author's version of a work that was submitted/accepted for publication in the following source:

Williams, Tim (2011) Design of sustainable transport : opportunities. In *New Urbanism and Smart Transport Conference*, 26 - 27 September 2011, Pan Pacific Hotel, Perth, WA. (Unpublished)

This file was downloaded from: http://eprints.qut.edu.au/48235/

© Copyright 2011 Tim William

Notice: *Changes introduced as a result of publishing processes such as copy-editing and formatting may not be reflected in this document. For a definitive version of this work, please refer to the published source:*

Design of sustainable transport: **Opportunities.**

Tim Williams BA Des

Queensland University of Technology

The need to find an alternative to our current transport situation is widely accepted. In most cities of the world, traffic congestion is commonplace and air pollution is normal. Road fatalities are a regular and almost accepted event. And (in most developed nations) as an indirect consequence of our transport choices, obesity is increasing at an alarming rate. The car is undeniably a major contributor to this situation. Additionally the very structure of our cities has evolved to the point that it can be creditably claimed that the city belongs to the car and not to humans.

There are however alternatives. There is a plethora of experimental vehicles in all shapes and configurations. And yet, the car is still king.

The question is, how do we pick a winner? What are the aspects of the car that make it so appealing? Are these aspects able to be translated into a more sustainable version? What do we need to incorporate in our designs of new vehicles to make them more appealing to the consumers?

In this paper I explore these questions and propose a list of design criteria for more sustainable transport options.

Introduction:

The demand for electric vehicles (EVs) is expected to increase significantly over the next few years.
For example, according to Ernst & Young's Global Automotive Center Detroit, 2010 – "Over 25% of drivers surveyed across US, Europe, China and Japan said they would likely consider purchasing plug-in hybrid (PHEVs) or electric vehicle (EVs), as soon as they become available on the market"
In the US, president Barrack Obama said in his state of the union address 2011. "With more research and incentives, we can break our dependence on oil with biofuels, and become the first country to have a million electric vehicles on the road by 2015"

The main drivers of this demand are:

(i) Increased fuel prices as a result of decreased availability of fuel supplies and/or increased excise;
(ii) The need to decrease traffic congestion;
(iii) The need to decrease air pollution
(iv) The desire to improve energy security.

The range of available EVs currently on the market is quite small. But, as demand grows, so will competition and therefore the range of products on offer is also likely to grow. (ValueID). So the demand to make the most, by design, of the unique constraints and opportunities offered by electric vehicles is expected to grow. (Sperling, 1995)

Much of the development effort concerning EVs tends to focus on solving the technical challenges of the electric, electronic and electro-mechanical aspects of electric vehicles. This is not surprising as the viability of EVs depends on functional, performance aspects such as range, acceleration and cost. The availability of cheap, lightweight batteries with high power density has been the major technical limiting factor in the viability of EVs. Although this situation has been improving rapidly in recent years, batteries still constitute a large percentage of the overall weight and cost of the vehicle so further improvements will make a big impact on the viability of the EV.

Although a great deal of effort has been focussed on technical issues, there have been numerous studies of different configurations of electric vehicles. For example the TREV (two-seater renewable energy vehicle) developed by the University of South Australia and the folding city car developed by the Massachusetts Institute of Technology. Or Segway's thought provoking Personal Urban Mobility and Accessability (PUMA) project.

As with most product ranges that go through a disruptive innovation stage it is reasonable to expect that initially EVs will have layouts and aesthetics that are hard to distinguish from ICE vehicles. An example of similar disruptive innovation is the transition from fixed, landline telephones to mobile, cellular phones. Initially the mobile phones were very similar to fixed phones but as the acceptance of the technology increased, the mobile phones developed into forms that took advantage of the new technology. It is therefore reasonable to expect that EVs will follow a similar path. However predicting the design direction that EVs will take is not an easy task. As difficult as it would have been in trying to predict back in the early 1980s that mobile phones would evolve to have touch screens and be internet and GPS enabled.

Design Constraints and Opportunities of Electric Vehicles

The design of any vehicle is a complex amalgamation of many, sometimes conflicting influences. User requirements, safety requirements, engineering requirements and manufacturing requirements all need to be considered and balanced tradeoffs need to be made. In the case of electric vehicles, some of these requirements will be identical to conventional cars and others will be completely different. For an example of what is unlikely to change, the aesthetic “tastes” of consumers, whilst always evolving, rarely changes quickly. However one of the things that has the potential to change is the internal layout. The layout of a conventional ICE vehicle is driven to a great extent by the mechanical layout; the placement of the engine, transmission, radiator and fuel tank all has a direct influence. In an electric car, these components are no longer required, replaced instead by a relatively simple motor and battery. The location of electric motors and batteries is far more flexible than engines, radiators etc and this will potentially have a significant influence of the overall design. So, it appears that there will be a considerable increase in the design possibilities brought about by flexibility of component layout.

EVs perform similar primary functions as ICE cars. For example they both are required to transport people from one place to another as comfortably and efficiently as possible. It is at the secondary function level where variations are likely to occur. Secondary functions are things like the ability to perform off-road, carry cargo, seating capacity etc. The secondary functions of all vehicles are where we see differentiation between makes and classes. We currently have sports cars, big family cars, small commuters, vans, 4 wheel drive vehicles and so on. Most of these ICE vehicles use a similar mechanical layout but are optimised for different applications. It is likely then that we will see a variety of EVs which have been optimised for different applications too. Additionally we are likely to see different categories of vehicles emerging that exploit the benefits of electric drive as well as being adapted to avoid the constraints.

For example, these are three manufacturing related aspects of EVs:

(i) EVs do not need to follow the mechanical layout that mandates the design of conventional vehicle
(ii) The simple mechanical components of electric cars reduce barriers of entry for manufacturers and may allow smaller manufacturers to compete and produce electric vehicles.
(iii) EVs need to be lighter and more energy efficient than internal combustion engine (ICE) vehicles

The first point (i) suggests that electric cars have the potential to be designed to offer greater flexibility in layout and form. For example the ability to place batteries flat under the floor of a car, lowers the centre of gravity and frees up the space normally required for a fuel tank. It also allows for arrangement for optimal weight distribution. Electric motors can be in wheels, further lowering the centre of gravity and freeing up the space required for the engine. A motor for each wheel offers true independent 4 wheel drive with none of the ground clearance limitations that axles and differentials create. This combination of a low C of G, optimum weight distribution as well as the ideal torque characteristics of electric motors shows great potential for both EV sports cars as well as EV off road vehicles.

The second point (ii) suggests there is the potential to see new, smaller manufacturers emerging offering a greater range of vehicles. Already, some of the most well known well known EV manufacturers are start-up companies that have never made ICE cars. Examples of this already emerging trend are the Reva Electric Car Company, Tesla Motors and newcomers, Fiskar automotive. Manufacturing the many components of an ICE car from the fuel tank to the exhaust pipe require specialised manufacturing techniques often requiring substantial investment in plant and equipment. Also many of the components have to be designed to fit only the one model of vehicle. An exhaust pipe is a good example. This high investment, complex assembly with specialised components is far more suited to very large organisations rather than smaller manufacturers. Components for EVs however are far more able to be generic. Electric motors are relatively simple with normally only one moving part. The function dictates the shape which is typically cylindrical and far smaller than an equivalent ICE. This suggests a situation where a few manufacturers of electric motors and batteries are likely to supply the same component to many car body manufacturers.

The third point (iii) means that current manufacturing materials and processes may not be the most appropriate for EVs. Deep drawn sheet steel has become the normal material for car body manufacture. It is cheap, robust, relatively easily worked and has well understood mechanical properties. The downside is that it is heavy with poor corrosion resistance. The weight is acceptable in an ICE car as long as a suitably powerful motor is chosen. With EVs, one of the inherent limitations is the energy available from batteries. Although batteries have improved significantly in recent years they still have nowhere near the energy density of petrol. The viability of electric vehicles lies in the efficiency of the conversion of stored energy into motion.

And less mass combined with less drag means less energy required to create this motion. The efficiency of the battery, controller and motor is already very good; the main potential for gain will be in the area of weight reduction. Lightweight materials have typically only been used in low production, high performance ICE cars due to the cost of the raw materials and the fact that these materials typically require more labour intensive processes. However with EVs some (and perhaps all) of that additional cost will be offset by less batteries. All design is influenced by the materials used and therefore we can expect to see this factor change the design outcomes as well as the design methods.

Taking the above points into consideration, we can expect to a greater range of EVs being designed by more manufacturers and we can expect these cars to be different to ICE cars. As the demand grows, the competition is also likely to grow. Innovation, performance and product differentiation will give competitive advantage as they always have.

Design Standards

Design Standards are also a very important consideration that influences the design of all vehicles. These design standards relate to both safety and functional standards. For example safety standards relate to things such as crash worthiness: crumple zones, seat belts, glass etc. Functional standards relate to things like indicators, mirrors and headlights. These standards tend to be country specific. For example, Australian standards mandate side intrusion bars in doors where other countries don’t. In spite of these variations there are sufficient similarities in the standards of most developed nations to allow multinational manufacturers to produce vehicles with little or no regional market variations. In the case of EVs some standards, for example headlight placement, are likely to remain the same however some standards such as those relating to fuel tanks will no longer be relevant and will be replaced by standards relating to other items such as batteries. It is possible that new standards may need to be introduced such as minimum noise standards to offset the possible increased danger to pedestrians, especially those with sight impairment. (Transport research laboratory, 2010) The irony of this is that one of the great benefits of EVs is the reduction of noise pollution.

If the full benefits of EVs are to be realised, it is likely that we will see a greater range of vehicle types. For example small, low speed, lightweight vehicles are ideal for the short journey that make up the majority of trips. This configuration suits the lower energy storage capabilities of batteries as well as the realities of modern urban lifestyles. However these light weight vehicles will be very difficult to design to current crashworthiness standards. In Europe, EVs with an unladen mass of 400kg or less and a motor no greater than 15kW are classified as quadricycles (European Parliament, 2002) and are not subject to the same design standards as larger vehicles. This, together with the congestion tax in London, has led to the popularity of the REVA G-Wiz. Similar classifications to the European quadricycle do not exist in Australia although 3 wheeled vehicles can be classified as motorcycles and therefore are subject to different standards.

Legislation will have an enormous effect on not just the design and availability of EVs but also on their popularity. This was seen in California, USA in 1990 when the California Air Resources board (CARB) issued a mandate that a percentage of vehicles sold must be “Zero Emission Vehicles” This encouraged vehicle manufacturers to make and sell EVs until the mandate was revoked. (Westbrook, 2001) In 2003 the City of London introduced a congestion charge for most vehicles. (London, 2011) EVs are exempt from this charge and this has resulted in a large increase in the use of EVs.

The challenge for legislators is to provide adequate safety standards whilst encouraging the uptake of EVs. It is likely to be different from one country to the next (unless some sort of international consensus is achieved) and it is also likely to change quickly. This creates an uncertain environment for EV designers.

If flexible platforms, simplified mechanics and OEM supplied technology allow a greater number of manufacturers to produce smaller runs of specialised niche products, and that legislation is likely to vary from one jurisdiction to another, then we are likely to see a far greater range of vehicles than are currently on the roads.

The Research Question

The design methodology used to develop conventional vehicles is quite distinct from the methodology used to design other products. Automotive design is often referred to as styling due to the high importance of aesthetics. Vehicles tend to be designed from the outside in, starting with a sketch before progressing to a clay model.

This approach has been developed over nearly 100 years and works well for existing ICE cars. However it does tend to mean that differentiation is based heavily on aesthetics. If there is little opportunity to vary layout due to the requirements of engines etc, then aesthetics and minor functional improvements are about the only points of differentiation left. If however there is more flexibility available to designers then possibly a styling led approach may not unleash the full scope of benefits. So, with a different design paradigm, are the existing design tools the most appropriate for this new paradigm?

PICKING A WINNER

Proactive vs Reactive Design

Design can be either reactive or proactive. That is it can either respond to existing demand within existing frameworks (reactive) or it can be used as a tool to create an innovative vision of the future (proactive). It can be argued that proactive design has been a part of automotive design in the form of the concept car for a long time. However it is typically used to gauge public reaction to new ideas which is a reactive approach. Reactive design is often know as “user-centred design” or “market pushed design” and tends to be convergent in nature. That is, as designers gain more detailed understanding of consumer preferences, the products from various manufacturers tend to become very similar with only superficial differences. Often the differences are technical. Cars are promoted based on the things like fuel consumption, horsepower, the number of airbags etc. Not diminish the importance of aesthetics on desirability of vehicles, the differences are however relatively superficial. For example, minor changes in the shape of headlights or a grill are often the main points of differentiation.

The process that creates proactive design is often known as design driven or design led innovation. It is “central to the practice of innovation” (Gaynor, 2002) This approach tends to be divergent, resulting in products that offer far greater differentiation than reactive design. This approach focuses more on the meaning of products rather than the technology. Electric vehicles offer the opportunity for a greater number of manufacturers offering a greater range of vehicles using perhaps identical, outsourced components. This means that they will look to differentiate a greater range of products based not on technology but on the meaning that they offer the customer.

So far, the new EVs entering the market superficially appear to be a conventional car with the ICE replaced by an electric motor (i.e. a reactive design approach.) This is probably a necessary approach initially until the consumers are comfortable with the technology. However as more manufacturers enter the market they will look for ways to differentiate their products and opportunities to diversify will become apparent.

Challenges

Standards

One of the greatest challenges is to find ways to demonstrate the potential benefits and potential demand of a new vehicle system or category in order to have legislators to set up the necessary frameworks to allow this to happen. It is part of my hypothesis that design can be a key enabling factor in this. That is that the design principles can be used as a tool to bring about legislative change.

Design standards are developed for ICE vehicles and are not necessarily suitable for EVs. (Transport research laboratory, 2010) For example one obvious new potential category of EV is the lightweight neighbourhood electric vehicle (NEV). This vehicle would be lightweight and designed for short distances and low speeds. This reflects the typical journey in our modern urban environment where short journeys are normal and congestion limits speed. The impact force in a collision increases exponentially with an increase in speed. This means that vehicles designed for low speeds require far less occupant protection than vehicles designed for higher speed use.

Currently the largest selling EV is the REVA, which is classified as a quadricycle in Europe and therefore exempt from some safety standards.

Another type of standard that will need to be considered is the standardisation of components. Batteries are a perfect example. One option considered to extend the range of EVs is that of battery swapping. For example the company Better Place has developed a system for swapping batteries. This relies on auto manufacturers using a standardised battery pack with standardised mountings.

Summary

The main hypothesis that arises from this is that design led innovation is a more appropriate methodology for designing EVs and that user centred design may not effectively address the constraints or opportunities that Electric Vehicles present.

Electric Vehicles offer far greater flexibility of design allowing for a wider variety of niche products.

Legislation will have a significant impact of the type of vehicle developed.

Major automotive manufacturers will need to re-evaluate the way in which vehicles are designed and are likely to experience competition from a wider variety of manufacturers.

Bibliography

European Parliament. (2002, march 18). COMMISSION DIRECTIVE 2002/24/EC. *2002L0024 — EN — 17.05.2005 — 003.001 — 1* .

Gaynor, G. H. (2002). *Innovation by Design.* New York: American Management Association.

London, T. F. (2011, 07 22). *Congestion Charging*. Retrieved from Transport For London.

Sperling, D. (1995). *Future Drive: Electric Vehicles and Sustainable Transportation.* Washington: Island Press.

ValueID. (n.d.). Retrieved 07 22, 2011, from Better Product Design: http://www.betterproductdesign.net/guide/valueid.html

Westbrook, M. H. (2001). *The Electric Car. Development and future of battery, hybrid and fuel-cell cars.* Stevenage, UK: Institution of Electrical Engineers.